Flash Memory Guide

Portable Flash memory for computers, digital cameras, cell phones and other devices

Kingston®, the world's leading independent manufacturer of memory products, offers a broad range of Flash cards and USB Flash drives (collectively called Flash storage devices) that employ Flash memory chips for storage. The purpose of this guide is to explain the various technologies and Flash memory offerings that are available.

Note: Due to Flash technology changes, specifications listed in this document are subject to change without notice.

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Its enduring commitment to service and support makes Kingston an easy choice for Flash memory.

1.0 Flash Memory: Empowering A New Generation of Flash Storage Devices

Toshiba invented Flash memory in the 1980s as a new memory technology that allowed stored data to be saved even when the memory device was disconnected from its power source. Since then, Flash memory technology has evolved into the preferred storage media for a variety of consumer and industrial devices.

IN CONSUMER DEVICES, FLASH MEMORY IS WIDELY USED IN:

- Notebook computers
- Personal Digital Assistants (PDAs)
- Global Positioning Systems (GPS)
- Solid-state music players such as MP3 players
- Personal computers
- Digital cameras
- Cell phones
- Electronic musical instruments
- Television set-top boxes

Flash memory is also used in many industrial applications where reliability and data retention in power-off situations are key requirements, such as in:

- Security systems
- Embedded computers
- Networking and communication products
- Retail management products (e.g., handheld scanners)
- Military systems
- Solid-state disk drives
- Wireless communication devices
- Medical products

2.0 Flash Card or USB Flash Drive Capacity

Some of a Flash storage device's listed capacity is used for formatting and other functions and thus is not available for data storage.

When a Flash storage device is manufactured, steps are taken to ensure that the device operates reliably and to permit the host device (computer, digital camera, PDA, cell phone, etc.) to access the memory cells — i.e., to store and retrieve data on the Flash storage device. These steps — loosely called "formatting" — utilize some of the memory cells within the device and thus reduce the capacity available for data storage by the end user.

Formatting includes the following operations:

1. Testing each memory cell in the Flash storage device.

2. Identifying all defective cells and taking steps to ensure that no data will be written to or read from a defective cell.

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Kingston's CompactFlash cards have a rated error specification of less than one (1) bit in 1,000,000,000,000,000 bits read, or one (1) bit per 10^{15} bits read.

3. Reserving some cells to serve as "spares." Flash memory cells have a long but finite lifetime. Therefore, some cells are held in reserve to replace any memory cells that may fail over time.

4. Creating a File Allocation Table (FAT) or other directory. To enable Flash storage devices to conveniently store and access customer files, a file management system must be created to allow any device or computer to identify the files stored in the Flash storage device. The most common type of file management system for Flash storage devices is the File Allocation Table (FAT), which is also used on hard drives.

5. Reserving some cells for use by the Flash storage device's controller, e.g., for storing firmware updates and other controller-specific information.

6. Where applicable, reserving some cells for special features. For example, the specification for Secure Digital (SD) cards requires reserved areas to support special copy protection and security features.

3.0 Features of Kingston's Flash Storage Products

Kingston's Flash storage devices offer many advantages for both consumer and industrial applications:

- **Flash Storage Device Warranty:** Kingston warrants that its Flash storage devices are free from defects in material and workmanship for the period specified below:
  - **SD, MMC, CF Flash Cards:** Lifetime†
  - **DataTraveler® USB Flash Drives and 15-in-1 Reader:** 5 years
  - **TravelLite SD/MMC Reader, K-PEX:** 1 year

For further details, see **kingston.com/company/warranty.asp**

- **Solid State:** Flash storage devices, as semiconductor storage devices, have no moving parts and thereby are not subject to the mechanical failure issues of hard drives. Their overall data reliability enabled them to dominate the convenience-oriented portable memory products market, operating silently with a zero decibel noise level.

- **Small Physical Size (or Form Factor):** Flash storage devices are designed to be easily transported. Convenience is an important criterion, especially for consumer and corporate applications.

- **High Data Reliability:** Flash memory is very reliable and many of the Flash storage device types also include Error Correction Code (ECC) checking to detect single-bit errors.

†*10-year warranty in France, Germany and Austria.*

Kingston engineers test and select high-performance controllers to ensure that Kingston's Flash cards are among the performance leaders in the industry.

For example, Kingston's CompactFlash® cards have a rated error specification of less than one (1) bit in 1,000,000,000,000,000 bits read (1 bit per 1015 bits read).

- **Kingston Flash Data Retention:** Kingston Flash storage devices are rated for up to 10 years under normal use. Important information should also be backed up on other media for long-term safekeeping.
- **Wear-Leveling Technology:** Kingston Flash storage devices incorporate controllers utilizing advanced wear-leveling technology, which distributes write cycles across the Flash card. Wear-leveling thus extends the useful life of a Flash memory card (for details, please see Kingston Flash Cell Endurance section, next).
- **Flash Cell Endurance:** For Multi-Level Cell (MLC) Flash, up to 10,000 write cycles per physical sector. For Single-Level Cell (SLC) Flash, up to 100,000 write cycles per physical sector.

  According to Toshiba, the inventor of Flash memory: "the 10,000 cycles of MLC NAND is more than sufficient for a wide range of consumer applications, from storing documents to digital photos. For example, if a 256-MB MLC NAND Flash-based card can typically store 250 pictures from a 4-megapixel camera (a conservative estimate), its 10,000 write/erase cycles, combined with wear-leveling algorithms in the controller, will enable the user to store and/or view approximately 2.5 million pictures within the expected useful life of the card."[1]

  For USB Flash drives, Toshiba calculated that a 10,000 write cycle endurance would enable customers to "completely write and erase the entire contents once per day for 27 years, well beyond the life of the hardware."

  SLC Flash based-products, typically found in Kingston's Elite Pro™/Ultimate Flash cards and DataTraveler II, II Plus – Migo Edition and Secure / Secure – Privacy Edition USB Flash drives, offer both high performance and high endurance.
- **Automatic Bad Sector Remapping:** Kingston Flash controllers automatically lock out sections with bad memory cells ("bad blocks") and move the data to other sections ("spare blocks") to avoid data corruption. During factory formatting (as described in Section 2), spare blocks are set aside on the Flash storage device for remapping bad sectors over time to extend the useful life and reliability of the Flash storage device.
- **High-Quality Connectors:** Kingston's Flash storage devices have connectors rated for more than 10,000 insertions.
- **Operating, Temperature and Humidity:** 32°F to 140°F (0° C to 60° C), 5% to 95% humidity (typical).

[1] *Toshiba press release, "Toshiba America Electronic Components, Inc. Releases Performance Research on MLC NAND Flash Memory for Consumer Applications," May 10, 2004*

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• **High-Capacity:** Flash storage devices can provide large storage capacities in a very small form factor. This flexibility makes them ideal for consumer uses, such as digital film or storage for MP3 music, where portability and convenience are important.

Please note: Some of the listed capacity is used for formatting and other functions and thus is not available for data storage. Please see Section 2 for details.

• **High-Performance:** Kingston's Elite Pro/Ultimate Flash cards and Hi-Speed DataTraveler USB Flash drives are faster than many standard Flash products and many competitive products. Kingston's engineers test and select high-performance controllers to ensure that Kingston's Flash cards are among the performance leaders. Please see the Appendix for information about USB and Hi-Speed USB performance. Kingston standard Flash products offer moderate performance levels for general purpose applications.

• **Low Power Consumption:** Unlike standard DRAM memory that needs to be constantly powered on to maintain its data, Flash memory is non-volatile and does not require power to maintain its data. Flash memory's low power consumption results in longer battery life for the host device.

• **Plug-and-Play Support:** Kingston's Flash memory line supports plug and play. With plug-and-play technology and compatible computer operating systems, a Flash storage device can be inserted into a computer or a Flash media reader and be quickly recognized and accessed by the computer.

• **Hot-Swapping Support:** Hot-swapping allows for plugging or unplugging Flash storage devices into a compatible computer or reader without needing to power off and restart the computer. This feature enhances the portability and convenience of Flash storage devices for transferring data, pictures or music between two computers or devices.

4.0 Non-Volatile NOR and NAND Flash Technologies

Unlike Dynamic Random Access Memory (DRAM), Flash memory is non-volatile. Non-volatile memory retains data even without being powered-on. For example, when a computer is turned off, all data that was in the computer's DRAM memory is lost; however, when a Flash storage device is removed from a digital camera, all data (and pictures) remains saved on the Flash storage device. The ability to retain data is key for Flash memory applications such as digital film for digital cameras, cell phones, PDAs and other transportable devices.

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There are two major technologies of Flash memory: NOR and NAND. Each technology has strengths that make it ideal for different kinds of applications, as summarized in the table below:

	NOR Flash	NAND Flash
High-speed Access	Yes	Yes
Page-Mode Data Access	No	Yes
Random Byte Level Access	Yes	No
Typical Uses	Cell Phones* BIOS Storage for PCs Networking Device Memory	PDAs Digital Cameras Cell Phones** MP3 players Solid State Disk Drives Set-Top Boxes Industrial Storage

4.1 NOR FLASH MEMORY

NOR, named after the specific data mapping technology (Not OR), is a high-speed Flash technology. NOR Flash memory provides high-speed random-access capabilities, being able to read and write data in specific locations in the memory without having to access the memory in sequential mode. Unlike NAND Flash, NOR Flash allows the retrieval of data as small as a single byte. NOR Flash excels in applications where data is randomly retrieved or written. NOR is most often found built into cellular phones (to store the phone's operating system) and PDAs and is also used in computers to store the BIOS program that runs to provide the start-up functionality

4.2 NAND FLASH MEMORY

NAND Flash was invented after NOR Flash, and is named after the specific mapping technology used for data (Not AND). NAND Flash memory reads and writes in high-speed, sequential mode, handling data in small, block sizes ("pages"). NAND Flash can retrieve or write data as single pages, but cannot retrieve individual bytes like NOR Flash.

NAND Flash memory is commonly found in solid-state hard drives, audio and video Flash media devices, television set-top boxes, digital cameras, cell phones (for data storage) and other devices where data is generally written or read sequentially.

For example, most digital cameras use NAND-Flash based digital film, as pictures are usually taken and stored sequentially. NAND-Flash is also more efficient when pictures are read back, as it transfers whole pages of data very quickly. As a sequential storage medium, NAND Flash is ideal for data storage.

NAND Flash memory is less expensive than NOR Flash memory, and can accommodate more storage capacity in the same die size.

Flash memory which stores a single bit per cell (e.g., a value of "0" or "1" per cell) is known as Single-Level Cell (SLC) Flash.

* *For operating system.*
** *For data storage.*

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CompactFlash cards were the first small form factor Flash memory cards.

5.0 Die-Stacking and Multi-Level Cell/Multi-Bit Cell Flash technologies

In order to economically increase the amount of bit-storage that a Flash memory chip can accommodate, manufacturers often utilize die-stacking and multi-level cell or multi-bit cell technologies. These technologies result in a Flash memory chip having the capability to store more data in a single chip.

5.1 DIE-STACKING

Many semiconductor manufacturers use a "die-stacking" technique to double a Flash memory chip's capacity. After the semiconductor wafer fabrication process, they cut out the Flash memory silicon "die" and then attach or stack two separate dies together.

For example, when a semiconductor manufacturer stacks two 1 gigabit dies together, they form a single 2 gigabit Flash memory chip.

Die-stacking allows for cost-reduced chip alternatives to the larger-capacity, single-die chips (called "monolithic" chips). Stacking two 8-gigabit chips together, for example, typically costs far less than buying a low-volume monolithic 16-gigabit chip. The 16-gigabit chip can then be used to build a 2-GB Flash card (single chip card), or a 4-GB Flash card (two chips on one card).

Die-stacking is similar to the DRAM chip-stacking technology that Kingston utilizes to produce high-end server modules. As a result, Kingston's die-stacked Flash cards are reliable and deliver high performance.

5.2 MULTI-LEVEL CELL (MLC) FLASH TECHNOLOGIES

NAND and NOR Flash memory chips store one (1) bit value (a "0" or a "1") in each cell. In multi-level Flash technologies, two (2) or more values are stored into each cell.

Intel Corporation has introduced NOR StrataFlash™; AMD has introduced NOR MirrorBit™ Flash. Other semiconductor manufacturers also manufacture their own multi-level cell technologies.

NAND MLC Flash technologies were introduced in late 2002, and Kingston has incorporated MLC Flash memory into its line of standard Flash cards and DataTraveler (DTI/XXX) USB Flash drives.

5.3 MULTI-BIT CELL (MBC) FLASH TECHNOLOGY

Multi-bit technology is a competing technology to Multi-Level Cell (MLC), and accomplishes the same goal by storing 2 bits per cell (or 4 values per cell). MBC technology is presently used in Infineon's TwinFlash™ memory.

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USB Flash drives offers an easy way to transfer files from a digital device to a computer.

6.0 Flash Storage Device Performance

Flash card storage device performance depends on the following three factors:

- **The specific Flash memory chips used:** Generally, there is a tradeoff between the high-speed and more expensive Single-Level Cell (SLC) Flash chips, and the standard speed and more affordable Multi-Level Cell (MLC) or Multi-Bit Cell (MBC) Flash chips. Kingston's high-performance Flash cards (Elite Pro/Ultimate) and DataTraveler II, II Plus – Migo Edition and Secure / Secure – Privacy Edition USB Flash drives all utilize the high-performance SLC Flash memory.

- **The Flash storage device's controller:** Today's Flash storage devices have a built-in Flash memory controller. This special chip manages the interface to the host device, and handles all the reads from and writes to the Flash chips on the Flash storage device. If the host controller is capable of supporting faster data transfer speeds, the use of optimized Flash controllers can result in significant time savings when reading or writing data into the Flash memory. For example, Kingston uses optimized, high-performance Flash controllers in its Elite Pro/Ultimate Flash cards and DataTraveler Hi-Speed USB Flash drives.

- **The host device to which the Flash storage device is connected to:** If the host device (computer, digital camera, cell phones, etc.) is limited to specific read and write speeds, using faster Flash storage devices will not deliver higher performance. For example, using a Hi-Speed USB Flash drive on a computer that supports only the slower USB speeds will not result in faster transfers. In addition, computers need to be properly configured to support faster transfers in both hardware and software. In the case of a PC, the system board will need to have built-in Hi-Speed USB 2.0 connectors, and the Operating System (e.g., Windows) will also need to have the proper USB 2.0 drivers installed in order to be able to support Hi-Speed USB transfers.

For details on USB Performance, refer to Appendix A.

Flash memory product manufacturers provide "x-speed" ratings for Flash cards. However, due to a lack of industry standards, comparing different Flash products may prove difficult for consumers. For details, see **kingston.com/flash/x**

Kingston works closely with global semiconductor and controller manufacturers to ensure that Kingston Flash cards deliver superior price/performance to its customers. For enthusiasts and advanced customers demanding the highest performance, Kingston offers the Elite Pro/Ultimate line of CompactFlash and SD cards, and the DataTraveler Hi-Speed USB Flash drives.

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7.0 Kingston's Flash Card Product Lines

There are several types of Flash storage devices that are available from Kingston:

- USB Flash Drives (DataTravelers)
- CompactFlash® Cards
- Secure Digital Cards (SD, miniSD, microSD)
- MultiMediaCards (MMCplus, MMCmobile)

7.1 USB FLASH DRIVES

Introduced in 2002, USB Flash drives offer an incredible combination of high storage capacity, fast data transfer rates, and great flexibility, all in the palm of your hand. Heralded as a floppy or CD drive alternative, USB Flash drives have far more storage capacity than that of a standard floppy disk or CD-ROM drive replacement. They provide an easy method for quick downloads and transferring digital files to and from your computer or device.

USB Flash drives incorporate NAND Flash and a controller in a capsulated case. USB Flash drives work with the vast majority of computers and devices that incorporate the Universal Serial Bus interface, including most PCs, PDAs, and MP3 players.

Kingston offers a full line of DataTraveler Hi-Speed USB Flash drives. Some DataTravelers also support password-protection for improved security. For details, please visit **kingston.com/flash/dt_chart.asp.**

7.2 COMPACTFLASH (CF) CARDS

CompactFlash, or CF cards, were the first small form factor Flash cards introduced in 1994. CF cards incorporate a controller and are about the size of a matchbook. CompactFlash cards incorporate an Integrated Device Electronics (IDE) interface similar to hard drives and ATA PC Cards. Kingston is a member of the CompactFlash Association, which sets the specifications for CF cards.

Kingston offers standard CompactFlash cards as well as high-performance Elite Pro and Ultimate lines.

Kingston's Elite Pro/Ultimate CompactFlash cards are among the fastest available in the industry. The high transfer rate is ideal for use on newer devices such as high-megapixel digital cameras, to ensure that the cameras save pictures faster and are quickly ready for the next shot.

CompactFlash cards come in a Type I form factor:

INTERFACE	VOLTAGE	PIN COUNT	SIZE IN MM
CompactFlash	3.3 and 5 Volts	50	Type I: 36.4 x 42.8 x 3.3

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Kingston offers a wide range of Secure Digital Cards

7.3 SECURE DIGITAL CARDS (SD, miniSD, microSD)

Secure Digital, introduced in late 2001, is a second-generation derivative of the MultiMediaCard (MMC) standard (see section 7.4).

The Secure Digital format includes several important technological advancements over MMC. These include the addition of cryptographic security protection for copyrighted data/music. The SD Card Association, of which Kingston is an executive member, sets the specifications for Secure Digital cards.

SD cards are slightly thicker than the original MMC cards. This means that devices designed to support SD cards may also accept MMC cards (if the host device is not strictly limited to SD media for SD copy protection management features). However, devices exclusively designed for MMC cards will not support the thicker SD cards at this time.

Kingston offers standard SD cards as well as high-performance Elite Pro and Ultimate SD cards. MiniSD (SDM) and microSD (SDC) are the mobile platform form factors of the SD card for use in cell phones and other portable devices. MiniSD and microSD are a fraction of the size of a standard SD card and, when used with the supplied Kingston adapter, can be used in standard SD device slots (for example, in Flash media readers).

INTERFACE	VOLTAGE	PIN COUNT	SIZE IN MM
Secure Digital	2.7 – 3.3 Volts	9	32 x 24 x 2.1
miniSD	2.7 – 3.3 Volts	11	20 x 21.5 x 1.4
microSD	2.7 – 3.3 Volts	8	15 x 11 x 1

7.4 MULTIMEDIACARD (MMCplus, MMCmobile)

MultiMediaCards, like SD cards, are one of the smallest Flash cards available, about the size of a postage stamp. They were introduced in 1997 and initially used in the mobile phone and pager markets. Today, they are commonly used in digital cameras, mobile phones, and MP3 players. MMC cards are generally backward-compatible with SD cards (so they can be plugged into SD slots) if the SD card's copy protection management features are not required by the host device. The MultiMediaCard Association, on which Kingston holds a position on the Board of Directors, sets the specifications for MMC.

In addition, MMC cards come in smaller form factors, originally called RS-MMC (Reduced-Size MMC) or RS-MMC DV (Reduced Size MMC – Dual Voltage). The original MMC

Specifically designed for high-speed image transfer, Kingston Flash media readers are an ideal solution for quickly viewing your digital images on your computer.

specification was updated from 3.x to 4.x. The new 4.x MMC cards are called MMCplus (replaces older MMC) and MMCmobile (replaces older RS-MMC DV).

The newer version of MMC cards launched in 2005 by the MultiMedia Card Association supports revision 4.x of the specification and is backward-compatible with the older MMC 3.x and RS-MMC 3.x cards (now discontinued).

MMCplus and MMCmobile cards offer higher performance than older MMC cards, and MMCmobile cards support lower voltage applications to reduce power consumption in cell phones. Kingston has discontinued the older MMC and MMC-RS 3.x cards and only offers the newer, backward-compatible MMCplus and MMCmobile cards.

INTERFACE	VOLTAGE	PIN COUNT	SIZE IN MM
MultiMediaCard	3.3 Volts	7	32 x 24 x 2.1
MMCplus	2.7 – 3.3 Volts	13	32 x 24 x 1.4
MMCmobile	1.8 – 3.3 Volts	8	18 x 24 x 1.4

MMC cards are designed for use in many popular portable devices. MMCmobile cards are the mobile platform form factors designed for use in cell phones and other portable devices. They are a fraction of the size of a standard MMCplus card and, when using the supplied Kingston adapter, can be used in standard MMCplus device slots (e.g., in Flash media readers).

8.0 Kingston Flash Media Readers

Flash media readers allow Flash storage devices to be used as portable storage for computers as well as for uploading or downloading of pictures, music, and other data without requiring the original host device (such as a digital camera or MP3 player), and without any additional drain on its batteries.

Flash media readers can enable the uploading and downloading of data at higher speeds than a host device is capable of supporting; for example, a USB reader will be much faster than a host device (such as a digital camera) using a serial interface. If a host device does not support high-speed transfers, the faster reader will significantly reduce the data transfer times.

Kingston offers Flash media readers for the convenient attachment of Flash storage devices to personal computers or notebooks.

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For Flash media, Kingston recommends the flexible and convenient 15-in-1 (fifteen form factors supported by a single reader) units that can accommodate most of the Flash card form factors available today and can be connected to any notebook with a Hi-Speed USB 2.0 port. Kingston also offer a convenient, portable, reader, TravelLite SD/MMC Reader for high-performance data transfers to systems supporting Hi-Speed USB 2.0.

9.0 CompactFlash to PC Card Adapters

Flash card adapters are convenient slip-in receiving frames that allow a CompactFlash card to be converted into an ATA PC Card (Type II) storage device.

Many notebooks and other devices supporting ATA Type II PC Cards also support CompactFlash cards when CF cards are inserted into a CF-ATA Flash card adapter.

10.0 For More Information:

For additional information on Kingston products, please visit: **kingston.com/flash.**

APPENDIX: USB PERFORMANCE

The Universal Serial Bus (USB) is emerging as the preferred interface to connect Flash card readers to computers.

The latest USB specification is USB 2.0. The older specification was USB 1.1. The USB 2.0 specification includes the USB 1.1 speeds for backward-compatibility reasons.

To understand what affects a Flash storage device's performance, one needs to consider several factors (see next page).

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Flash Memory Chip Technology Single-Level Cell (SLC) vs. Multi-Level Cell (MLC) and Multi-Bit Cell (MBC)	In general, Flash storage devices built with Single-Level Cell (SLC) NAND Flash, such as Kingston's Elite Pro/Ultimate Flash cards or the DataTraveler II, II Plus – Migo Edition or Secure / Secure – Privacy Edition USB Flash drives, will deliver higher performancean the standard Multi-Level Cell (MLC) NAND Flash or Multi-Bit Cell (MBC) NAND Flash based cards or DataTraveler. Standard Flash cards or the DataTraveler USB Flash drives deliver the best price/performance value for most users of digital cameras, PDAs, cell phones, and other electronic devices. Elite Pro/Ultimate Flash cards or Hi-Speed Data Traveler 2.0 USB Flash drives will deliver faster reads and writes, ideal for advanced users, photography professionals, and enthusiasts. Of course, to achieve the performance benefit of faster Flash cards or USB Flash drives, users must have compatible high-speed devices and properly configured computers. Some digital cameras and other devices require SLC NAND Flash based high-performance Flash cards for proper functionality.
Host Consumer Devices Digital cameras, mobile phones, PDAs and other devices	The built-in controller interfacing with Flash cards or USB Flash drives in many consumer devices may have limited bandwidth. Please consult your user manual or contact the device manufacturer for specifics. All else being equal, the achievable performance level will be the minimum data transfer level supported by the host controller or the Flash card or USB Flash drive.
• Connecting Flash cards to computers through 15-in-1 and TravelLite readers. • Connecting USB Flash drives directly to a computer's USB slot	The USB 2.0 specification also includes the older USB 1.1 specification for backward-compatibility reasons USB Flash Drives and Digital Media Reader-writers require the following logos to indicate performance levels: USB logo: transfers data at a maximum of 12 megabits per second (12 Mb/s or 1.5 MB/s). It is also referred to as Original USB or USB 1.1, and is also compatible with USB 2.0 Full-Speed (with a maximum speed of 12 Mb/s or 1.5 MB/s). Hi-Speed USB logo: transfers data at a maximum of 480 megabits per second (480 Mb/s or 60 MB/s). It is also called USB 2.0 Hi-Speed. Hi-Speed USB is up to 40X faster than USB and fully backward-compatible with USB through its USB 2.0 Full-Speed mode (with a maximum speed of 12 Mb/s or 1.5MB/s). If both the Flash media reader and computer properly support Hi-Speed USB, Kingston's high-performance Elite Pro/Ultimate Flash cards will deliver greater performance over standard Flash cards. Similarly, all Kingston's DataTraveler USB product family will deliver higher performance on a computer supporting Hi-Speed USB transfers.

Please note: Some of the listed capacity is used for formatting and other functions and thus is not available for data storage.

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